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Deformation Response of Oil Reservoir Induced by Water Injection

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Outline

1 Introduction

2 Model and Experiment

3 Results and Discuss

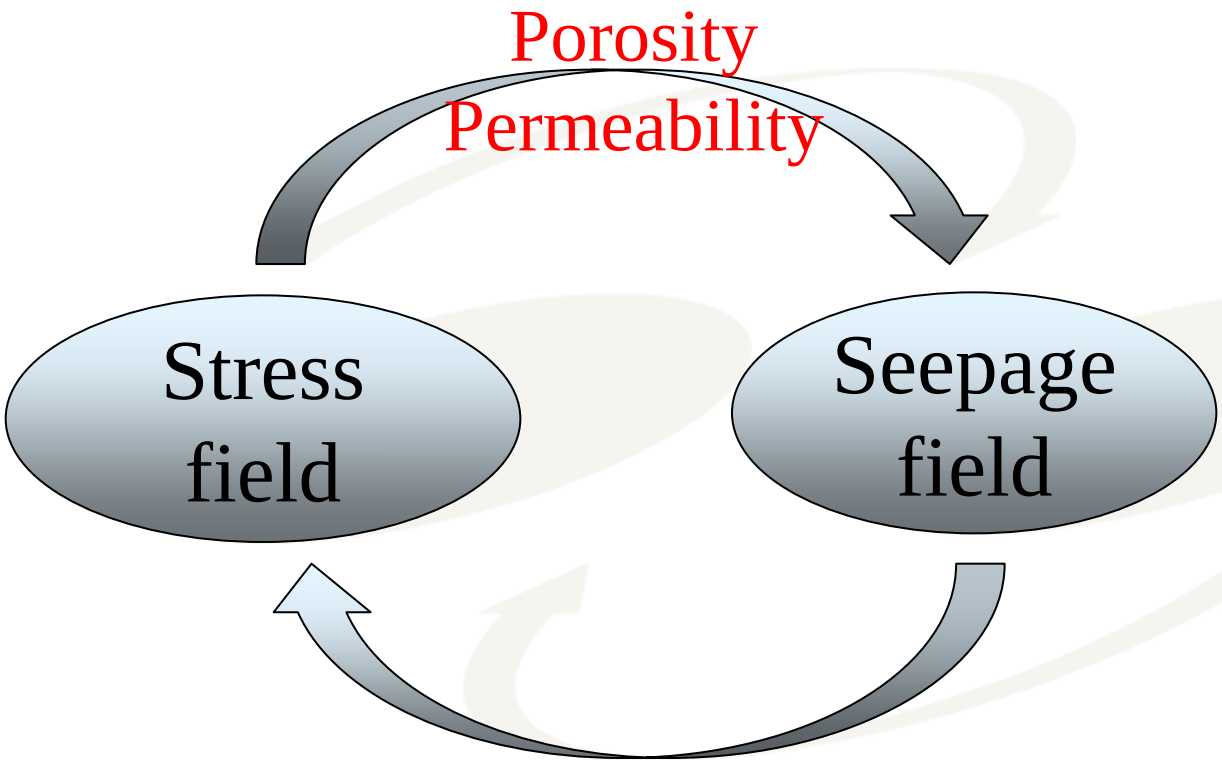
4 Conclusion

1.Introduction

- Water injection may break the balance of stress and pore pressure in the reservoir and cause the re-distribution of them.
- The uneven filed after redistribution is the main reason of the deformation of reservoir, and the initiation and propagation of faults.
- It is necessary to study the mechanism of deformation response induced by water injection in reservoir.
- The main approach is hydro-mechanic coupling theory.

1.Introduction

- Hydro-mechanic coupling theory



2.Model and Experiment

2.1 Mathematical model

Equation of stress

$$\frac{3K_V(\sigma_e)+G(\sigma_e)}{3}\frac{\partial \varepsilon_V}{\partial i}-G\nabla^2 u_i+\frac{\partial p}{\partial i}-F_i=0$$

Equation of seepage

$$\nabla\cdot\left[\frac{k(\sigma_e)}{\mu}\cdot\nabla(p+\rho g z)\right]=n(\sigma_e)\beta_p\frac{\partial p}{\partial t}-\frac{\partial \varepsilon_V}{\partial t}$$

Relationship between seepage and stress

$$k(\sigma_e)=k_0\exp(-\alpha_1\sigma_e)$$

$$n(\sigma_e)=n_0\exp(-\alpha_2\sigma_e)$$

2.Model and Experiment

2.1 Mathematical model

Effective stress

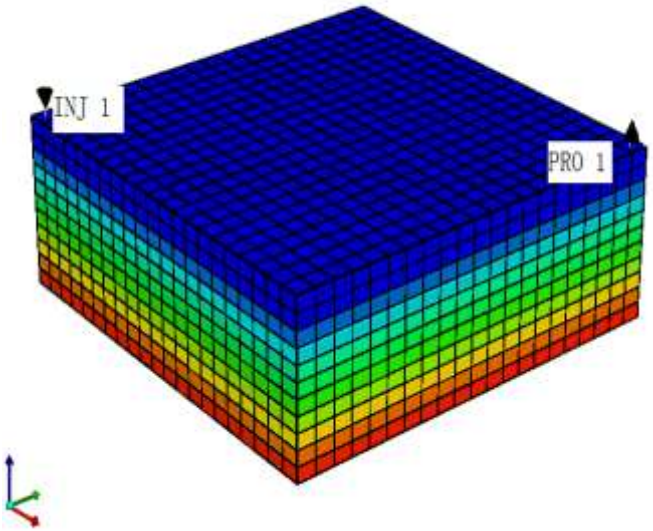
$$\sigma_e = \sigma - \alpha p$$

Hooke law

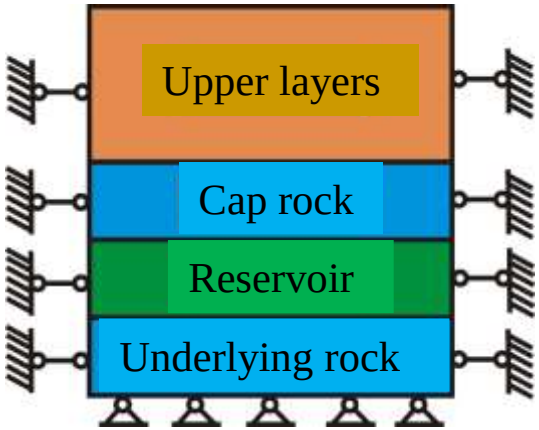
$$\sigma_e = E(\sigma_e)\varepsilon_{\mathrm{V}}$$

2.Model and Experiment

2.2 Numerical Model



Numerical Model
(quarter reservoir model of five spots)



Boundary Condition

Top depth：1200m
Thickness：60m
Permeability I、J：100mD
Permeability K：10mD

Horizontal stress：35MPa
Vertical stress：42MPa
Young’s module：2.9e5MPa
Poisson's ratio：0.25

2.Model and Experiment

2.3 Experiment Design

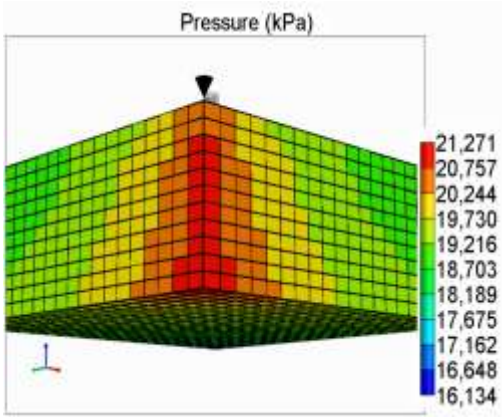
Case1：Different depth

Case2：Different injection-withdraw ratio

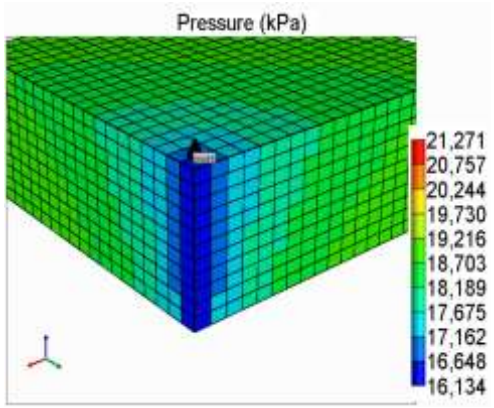
Case3：Different elastic module

3.Results and Analysis

Results（Pore pressure）



Pressure around injection well



Pressure around production well

Injector:

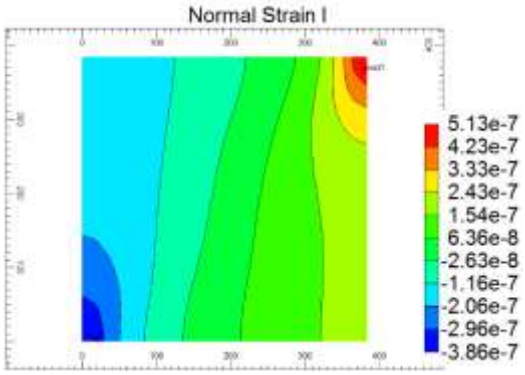
pear-shaped region (bigger on the bottom and smaller on the top)

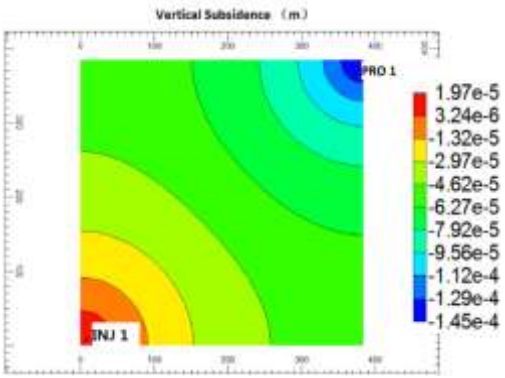
Producer :

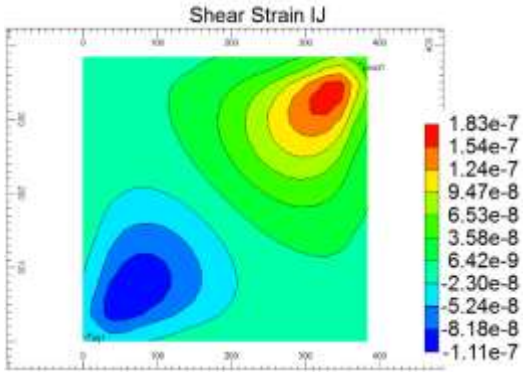
inverted-pear-shaped region (smaller on the bottom and bigger on the top),

3.Results and Analysis

Results（field of strain）







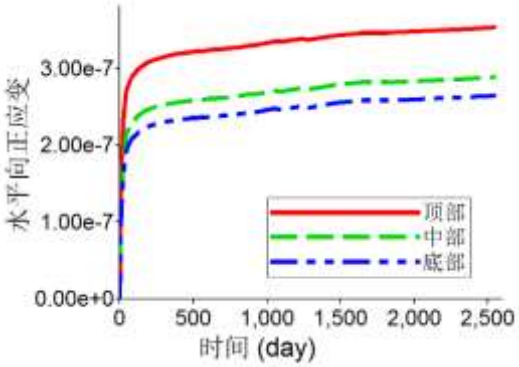
Normal strain　　Shear strain　　Vertical displacement

Bigger strain and deformation are observed around two wells. Simultaneously, the strain and deformation in the segment between two wells are lower than the surrounding of two wells.

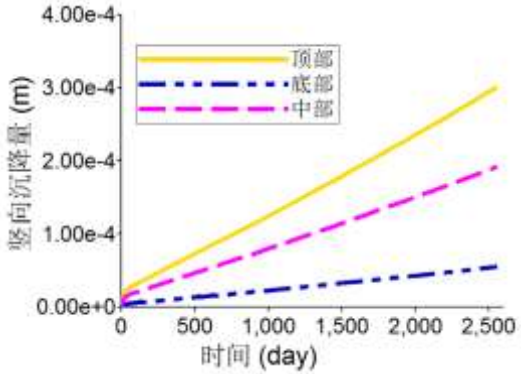
3.Results and Analysis

Results（Depth）

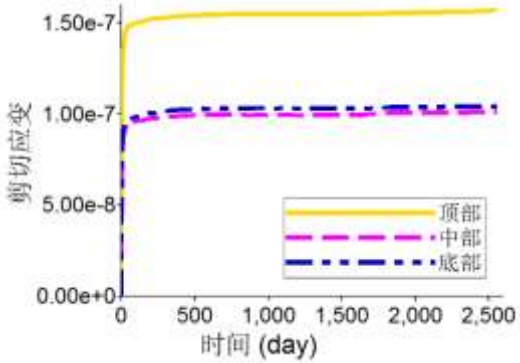
Normal strain



Vertical displacement



Shear strain



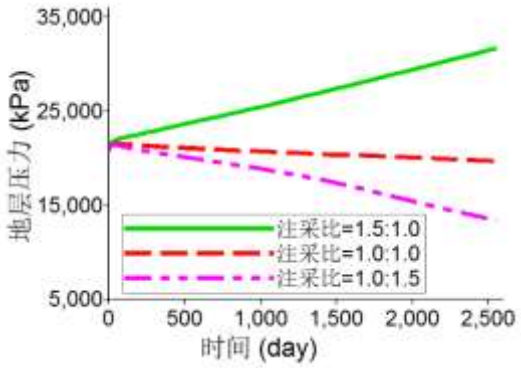
The normal strain and vertical subsidence reach maximum value at the top of reservoir and decrease with stratum depth increasing.

The shear strain of top and bottom in reservoir is bigger than in the centre, and the biggest appears on the top of the reservoir model.

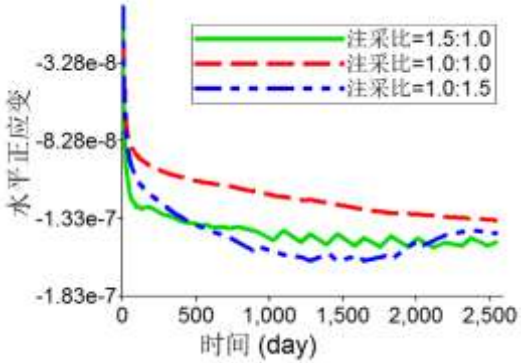
3.Results and Analysis

Results（ Injection withdrawal ratio, IWR ）

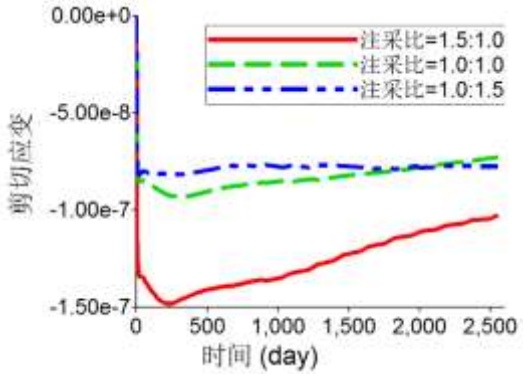
Pore pressure



Normal strain



Vertical Displacement



When IWR>1(=1.5:1), the pressure increases and the effective stress decreases. Otherwise, when IWR<1, the pressure is less and the effective stress is greater.

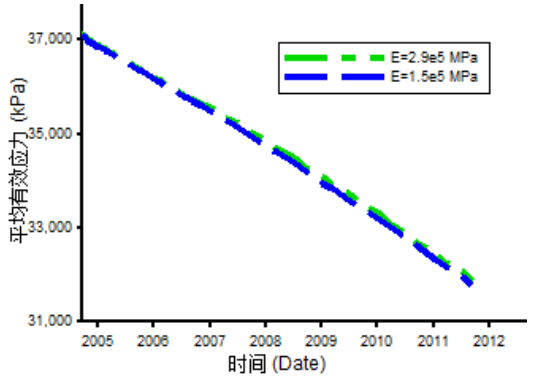
The value of normal strain when IWR≠1 is bigger than balance injection performance（IWR=1）.

Besides, the shear strain increases with IWR>1 and is in a low and balance value with IWR≤1.

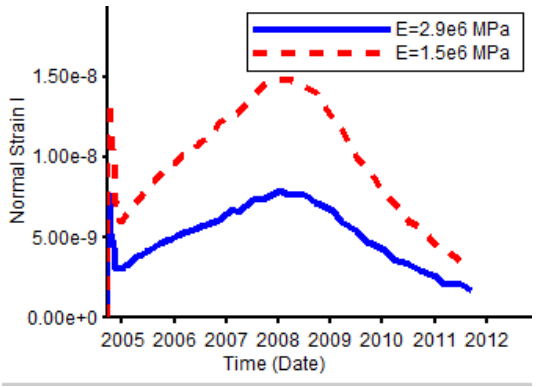
3.Results and Analysis

Results（Elastic module）

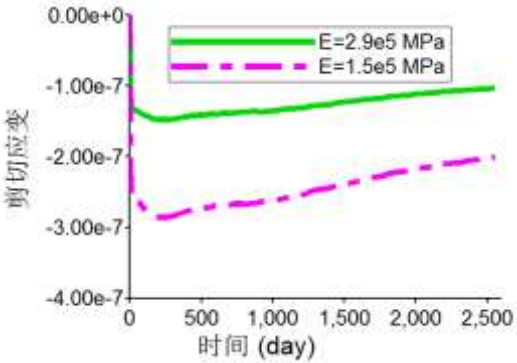
Effective Stress



Normal Strain



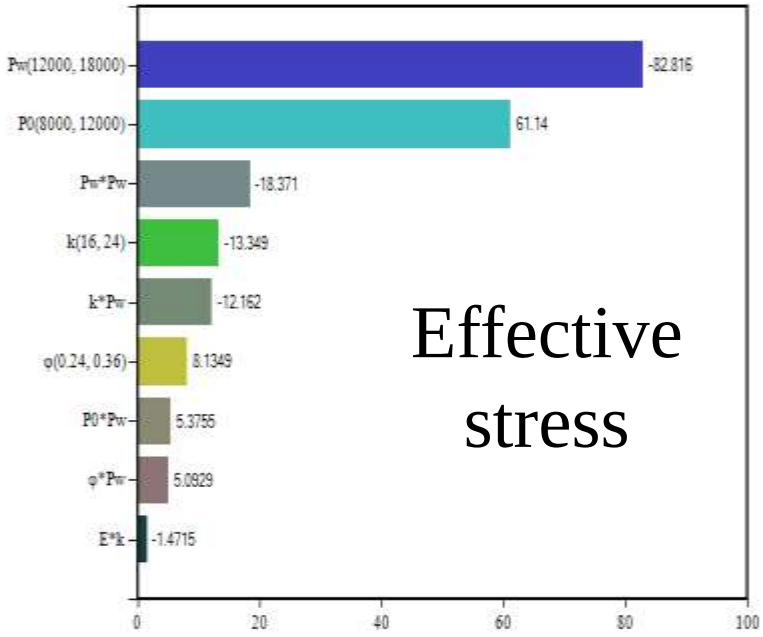
Shear Strain



Elastic modules mainly effects the strain and deformation of rocks. And strain and deformation are negatively related to the elastic modulus.

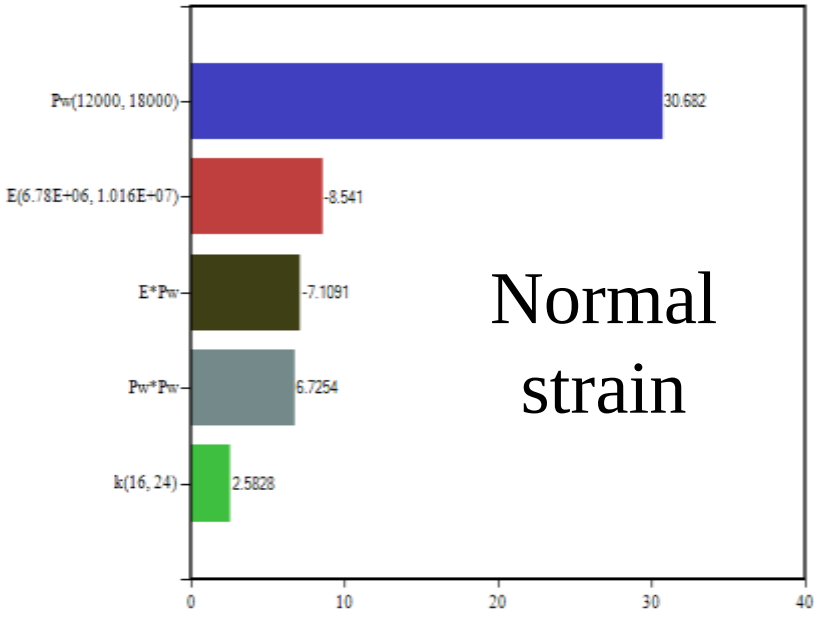
3.Results and Analysis

Results（sensitive analysis）



Effective stress

Injection pressure
Initial pressure of reservoir
Permeability



Normal strain

Injection pressure
Elastic module
Permeability

4. Conclusion

1. Water injection leads to redistribution of stress.
2. The deeper the layer is, the smaller the normal strain and vertical displacement is. The largest shear strain is on the top, while the smallest is in the center.
3. Different injection-withdraw ratios have significant influence on formation’s deformation.
4. Elastic modulus mainly influences the deformation of the stratum, and deformation size is negatively related to the elastic modulus.

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Thank You ！

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